Carderock Division, Naval Surface Warfare Center

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Hydromechanics Directorate
Research and Development Report

Summary of Seakeeping Trials Aboard SLICE

by
Terrence R. Applebee
Dennis A. Woolaver

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Seakeeping trials were conducted onboard SLICE, a small waterplane area prototype developed by Lockheed Martin under cooperative agreement with the Office of Naval Research (ONR). Testing was performed off the coast of Oahu, Hawaii in April 1998. A summary of measured ship motions is presented for a variety of speeds and headings in Sea State 4. Comparisons are shown with motion control engaged and disengaged.

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ABSTRACT

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ADMINISTRATIVE INFORMATION

This work was performed by the Seakeeping Department, Code 5500, at the Naval Surface Warfare Center, Carderock Division (NSWCCD), and was sponsored by the Office of Naval Research (ONR). Funding for this project is identified at NSWCCD as Work Unit 1-5300-929.

INTRODUCTION

In March-April 1998, NSWCCD was tasked by ONR to conduct performance and seakeeping trials onboard the 104-foot SLICE ship. Derived from Small Waterplane Area Twin Hull (SWATH) technology, SLICE was developed by Lockheed Martin for ONR and built by Pacific Marine in Honolulu, Hawaii. Built for high speed (30+ knots) and stability in high sea conditions, the aluminum-hulled SLICE features four submerged hulls with stabilizers, twin diesel engines, and controllable pitch propellers. Propulsion is provided at the forward two hulls which are inset approximately eight feet from the aft hulls (see Figure 1). In addition, SLICE utilizes a PC-based touchscreen system for ballast and motion control as well as for subsystem monitoring and alarms.

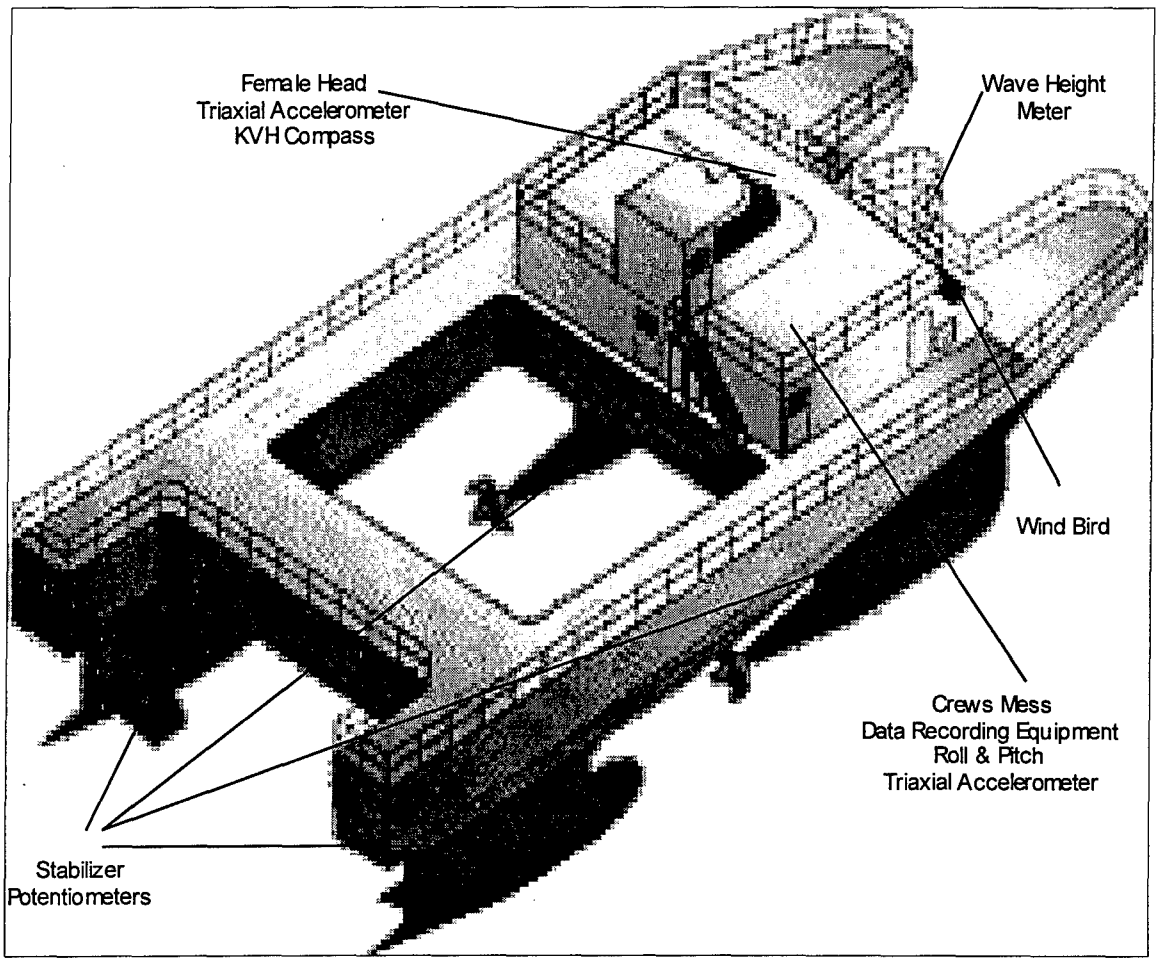
Seakeeping trials were conducted in the waters off Oahu, Hawaii during 3-6 April. Twenty-four channels of data were collected to quantify the environment (waves and wind), ship motions (including roll, pitch, and accelerations), and control surface movement. This report documents and summarizes the test procedures, instrumentation, and resulting measured data.

APPROACH

Instrumentation

A Ship Motion Recorder (SMR) package was installed on SLICE in March 1998. This system consisted of NSWC-installed sensors and ship systems tie-ins, signal conditioning, and data recording capability. Table 1 presents a summary of the sensors and locations, as well as the associated data channels. Data recording was performed using a Compaq 486/50 computer, Scientific Solutions Labmaster A/D board, and Frequency Devices 2-Hz, anti-aliasing filters. Data were stored on the hard drive of

the computer as well as on a removable 90-Mbyte Bernoulli cartridge. Roll and pitch angles/rates were measured with a Watson Industries inclinometer sensor (Model ADS-C232-1A). Two Columbia Research Laboratories triaxial accelerometers were used to measure the longitudinal, transverse, and vertical accelerations. Wave height was measured with a TSK shipborne wave meter which also provided a vertical bow acceleration measurement. Relative wind speed and wind direction were recorded with a Young yacht wind bird. Heading was provided by KVH Industries Azimuth 314AC fluxgate compass. Four linear potentiometers with a wrap around each stabilizer shaft were utilized to record stabilizer angular positions.



DISPLACEMENT	180 Long Tons (183 Metric Tons)
LENGTH OVERALL	104 Feet (31.7 Meters)
BEAM (Max)	55 Feet (16.8 Meters)
DRAFT (Full Load)	14 Feet (4.3 Meters)

Figure 1 – SLICE particulars & instrument locations

Table 1 – Data Channel Summary

CHANNEL	UNITS	SENSOR	LOCATION
1. Pitch Angle	degrees	Watson Meter	Crews Mess
2. Roll Angle	degrees	Watson Meter	Crews Mess
3. Pitch Rate	deg/sec	Watson Meter	Crews Mess
4. Roll Rate	deg/sec	Watson Meter	Crews Mess
5. Yaw Rate	deg/sec	Humphrey Rate Sensor	Crews Mess
6. Vertical Acceleration	g's	Columbia Triaxial Accelerometer	Crews Mess
7. Longitudinal Acceleration	g's	Columbia Triaxial Accelerometer	Crews Mess
8. Transverse Acceleration	g's	Columbia Triaxial Accelerometer	Crews Mess
9. Vertical Acceleration	g's	Columbia Triaxial Accelerometer	Female Head
10. Transverse Acceleration	g's	Columbia Triaxial Accelerometer	Female Head
11. Longitudinal Acceleration	g's	Columbia Triaxial Accelerometer	Female Head
12. Relative Wind Speed	knots	Young Wind Bird	Starboard 01 Deck
13. Relative Wind Direction	degrees	Young Wind Bird	Starboard 01 Deck
14. Wave Height	feet	TSK Shipborne Wave Meter	Bow on Centerline
15. Wave Period	seconds	TSK Shipborne Wave Meter	Bow on Centerline
16. Relative Bow Motion	feet	TSK Shipborne Wave Meter	Bow on Centerline
17. Bow Acceleration	g's	TSK Shipborne Wave Meter	Fwd Storage Locker
18. Stbd Stabilizer Position	deg	Linear Potentiometer	Aft Starboard Hull
19. Port Stabilizer Position	deg	Linear Potentiometer	Aft Port Hull
20. Stbd Canard Position	deg	Linear Potentiometer	Fwd Starboard Hull
21. Port Canard Position	deg	Linear Potentiometer	Fwd Port Hull
22. Heading	deg	KVH Compass	Male Head
23. Ship's Pitch	deg	Lockheed Martin Ship Feed	Pilothouse
24. Ship's Roll	deg	Lockheed Martin Ship Feed	Pilothouse
25. Aft Stbd Control Surface	deg	Lockheed Martin Ship Feed	Aft Starboard Hull
26. Aft Port Control Surface	deg	Lockheed Martin Ship Feed	Aft Port Hull
27. Forward Stbd Control Surface	deg	Lockheed Martin Ship Feed	Fwd Starboard Hull
28. Forward Port Control Surface	deg	Lockheed Martin Ship Feed	Fwd Port Hull

Methodology

Seakeeping trials were performed off the southern coast of Oahu, Hawaii on 3-6 April 1998. Prior to entering open water, draft marks were noted both fore and aft at zero speed. Once in waters sufficiently beyond the island and away from shipping channels, a standard series of data runs were conducted to measure ship motions at a variety of headings with respect to the waves. Periodic zero-speed wave height runs were performed for approximately 30 minutes to characterize the encountered seaways. Because consideration was given to balancing the transit time and the test time available each day, subtle changes in wave direction (wave-wrapping) sometimes occurred during steady state runs as the ship approached the island corners. These observations were noted in the trial log book.

Because SLICE is equipped with a motion control system, an attempt to test twice at each heading with respect to the waves was made: once with motion control engaged followed by motion control turned off. Thus the overall reduction in motion could be assessed. However, it should be noted that no attempt was made to evaluate the control

algorithms per se. A Lockheed-Martin representative was present during the seakeeping trials to monitor the control system, and the motion control settings (gains) and setpoints (static offsets) were input by the captains using their standard operating procedure. Table 2 presents a summary of the data runs conducted.

Table 2 – Synopsis of Seakeeping Trial Runs Performed

RUN NO.	DATE-TIME	RUN LENGTH (min)	SEA STATE*	HEADING WRT WAVES	SPEED (kt)	MOTION CONTROL	COMMENT
51	030936Z APR98	30.0	HIGH 4	Head	0	-	Wave height measure
52	031007Z APR98	30.0	HIGH 4	Head	23	ON	Slamming with spray
53	031051Z APR98	30.0	HIGH 4	Stbd Qtr	23	ON	
54	031143Z APR98	30.0	HIGH 4	Stbd Qtr	23	OFF	
55	031215Z APR98	20.0	HIGH 4	Head	0	-	Wave height measure
56	031245Z APR98	30.0	HIGH 4	Port Beam	23	OFF	
57	031321Z APR98	30.0	HIGH 4	Stbd Beam	23	ON	
58	031402Z APR98	30.0	HIGH 4	Port Bow	23	ON	Occasional slam
59	031509Z APR98	30.0	HIGH 4	Stbd Bow	18	ON	Reduce speed due to waves
60	031546Z APR98	30.0	HIGH 4	Following	23	ON/OFF	Smooth ride
61	031622Z APR98	20.0	MID 4	Head	0	-	Wave height measure
62	031648Z APR98	20.0	MID 4	Head	23	OFF	
63	031712Z APR98	20.0	MID 4	Head	23	ON	Occasional slam/wetness
65	4-Apr-98	30.0	MID 4	Head	0	-	Wave height measure
66	4-Apr-98	30.0	MID 4	Following	8	ON	Surfing/bumpy
67	4-Apr-98	30.0	MID 4	Following	8	OFF	
68	4-Apr-98	30.0	MID 4	Port Bow	8	OFF	Occasional slam w/ spray
70	4-Apr-98	30.0	MID 4	Port Bow	8	ON	Occasional spray
71	4-Apr-98	30.0	MID 4	Stbd Beam	8	ON	
72	4-Apr-98	30.0	MID 4	Stbd Beam	8	OFF	
73	4-Apr-98	17.7	MID 4	Stbd Bow	23	OFF	
74	050818Z APR98	30.0	HIGH 4	Head	0	-	Wave height measure
75	050917Z APR98	30.0	HIGH 4	Head	8	ON	Occasional shudder
76	050952Z APR98	30.0	HIGH 4	Head	8	OFF	Some slamming
77	051058Z APR98	20.0	HIGH 4	Head	0	-	Wave height measure
78	051120Z APR98	20.0	HIGH 4	Following	23	ON	
79	051152Z APR98	9.8	HIGH 4	Following	23	ON	Continuation of Run 78
80	051203Z APR98	30.0	HIGH 4	Following	23	OFF	
81	051242Z APR98	30.0	HIGH 4	Stbd Qtr	8	OFF	
82	051313Z APR98	30.0	HIGH 4	Stbd Qtr	8	ON	
83	051356Z APR98	30.0	HIGH 4	Port Bow	15	ON	Pronounced surging
84	051430Z APR98	30.0	HIGH 4	Port Bow	15	OFF	Some heavy slams/wetness
85	051502Z APR98	30.0	HIGH 4	Stbd Beam	15	OFF	Occasional slams on struts
86	051538Z APR98	30.0	HIGH 4	Port Beam	15	ON	Mid-run course correction
87	051620Z APR98	30.0	HIGH 4	Head	15	ON	Shuddering
88	051655Z APR98	30.0	HIGH 4	Head	15	OFF	Occasional slam/wetness
92	061003Z APR98	30.0	LOW 4	Head	0	-	Wave height measure
93	061054Z APR98	30.0	LOW 4	Port Qtr	15	ON	Comfortable ride
94	061131Z APR98	30.0	LOW 4	Port Qtr	15	OFF	Good ride, meandering roll/yaw
95	061202Z APR98	20.3	HIGH 4	Head	0	-	Wave height measure
96	061227Z APR98	30.0	HIGH 4	Stbd Bow	23	ON	Redundant run; some slam
97	061301Z APR98	30.0	HIGH 4	Following	15	ON	
98	061336Z APR98	15.1	MID 4	Head	0	-	Wave height measure
99	061354Z APR98	30.0	MID 4	Following	15	OFF	
100	061451Z APR98	25.5	LOW 4	Head	0	-	Wave height measure
101	061519Z APR98	30.0	LOW 4	Head	8	OFF	Predominantly swell
102	061551Z APR98	30.0	LOW 4	Head	8	ON	

* Sea State 4 range of significant wave height: 4.1 to 8.2 feet (1.25 to 2.5 meters)

TRIAL NARRATIVE

Four days of testing were performed beginning 3 April 1998. The test matrix was to include Sea States 3 and 4, at two different ship speeds. In order to ensure a proper statistical characterization of the motions, 30-minute run times were used per heading/speed combination. When activated, motion control settings were input manually by the ship operator to maximize ride comfort.

Day 1

A briefing was held dockside to instruct the ship's crew and test personnel on trial procedures and goals. Initial "zero conditions" were noted for the control surfaces:

Port canard	-0.8 degrees
Starboard canard	-2.4 degrees
Port stabilizer	+0.3 degrees
Starboard stabilizer	+0.7 degrees

Initial drafts marks were recorded as well: forward draft of 14'1" (4.29 m) and aft draft of 14'7" (4.45 m) The transit to the operations area was due south and the first wave height measurement (Run # 51) indicated an 8-foot significant wave height (high Sea State 4) with winds of 35 knots. The first run (#52) was into the waves (head seas) at 23 knots with motion control settings for roll (R), pitch (P), and yaw (Y) at .56, .60, and .34, respectively. During this run the motion control failed and required a reboot. This heading produced quite a few slams and frequent spray. Sea conditions appeared to increase in severity during this run. At the end of the run, the ship operator determined that the conditions were too rough to continue at this heading with motion control off, so a more benign starboard stern quartering heading was recorded (#53) to bring the ship back into the island lee. Motion control remained on at R=.52, P=.72, and Y=.34. The yaw control was subsequently increased to .5 to compensate for excessive yawing at this heading. Approximately half way through this run, the static fin angles needed to be reset to the "zero conditions," having failed to do so after the previous run's reboot of the motion control system.

The next run (#54) was a starboard stern quartering condition at 23 knots (RPM set at 1950 and 90% pitch on the propeller). Motion control was disengaged except for yaw (set at .36) which was required to help steer. The bow was observed to dip occasionally causing spray over the bow. At the conclusion of this run, a short 20-minute wave height measurement (#55) was made to confirm the high Sea State 4.

A port beam wave condition at 23 knots with motion control off was conducted next. Some course variation occurred due to the motion control system temporarily going offline during this run. A reciprocal starboard beam condition at 23 knots followed (#57) with motion control set at R=.6, P=.36, Y=.32. During this run, a problem with the port hydraulics was encountered and recitified, and the ship operator ballasted on the fly to keep the vessel's nose up. Occasional bumpiness and spray were noted.

Run #58 was a port bow sea condition at 23 knots with motion control engaged (R=.54, P=.46, Y=.34). Once again this heading took the ship into rougher sea conditions with prevalent slamming and wetness. Speed was reduced to 18 knots for the next run (#59) in a starboard bow sea with motion control on and the pitch setpoint at 1.5° up.

The next run (#60) began with motion control on (R=.34, P=.58, Y=.40) in a following sea at 23 knots. This presented a exceptionally smooth ride so motion control was disengaged for about the last 5-10 minutes of the run to assess qualitatively the effects of motion control. No significant difference was experienced. A wave height measurement was subsequently performed (#61).

The last two runs for this test day were at head sea conditions and 23 knots. Run #62 was with motion control off and run #63 was with motion control on. An occasional slam and wetness was noted during the last run where wave-wrapping due to the close proximity of the island produced seas slightly to port.

Day 2

On 4 April 1998, the ship was delayed in getting underway until the afternoon due, in part, to the rough conditions encountered the day before. The plan of the day was to stay closer to the island and do slower speed(s). As we got underway, the forward and aft drafts were noted as 14'3" (4.34 m) and 13'10" (4.22 m), respectively. The first wave height run (#65) indicated a mid-Sea State 4 (6.4-foot, or 1.95-meter, significant wave height). The first seakeeping run (#66) was a following sea condition at 8 knots with motion control on. This speed was chosen over 10 knots to avoid the hump speed curve and represented an RPM of 950 with propeller pitch set at 70%. Motion control settings were R=.62, P=.80, Y=.43, and the pitch setpoint adjusted to 0.8° to keep the bow from digging in. Noticeable surfing was observed and the ride was a bit jumpy/bumpy. With motion control off for the next run (#67), a yaw setting of .42 was maintained to assist in steering. RPM and propeller pitch was the maintained. Relative wind was observed to be about 18 knots and relative direction from the port stern.

Run #68 was a port bow quartering sea condition at 8 knots with motion control off (continuing to maintain Y=.42). Relative wind was noted to be 23 knots off the port beam. Ship experienced digging in and noticeable pitching even with the pitch setpoint at 0.8°. Several slams with spray were noted. The next run (#70) was identical except with motion control activated (R=.56, P=.60, Y=.36). The pitch setpoint was adjusted to 0.4°. The seas appeared to get rougher during the run with occasional spray noted.

The next set of runs was for starboard beam seas at 8 knots with motion control on (#71) and motion control off (#72), and a pitch setpoint at zero. No noticeable difference was observed in the ride between motion control on (R=.7, P=.28, Y=.36)

or off. The last run of the day (#73) was a 23-knot, starboard bow quartering sea. RPM was 1950, propeller pitch set at 90%. Drafts noted at the end of the test day: 14'3" (4.34 m) forward, 14'5" (4.39 m) aft.

Day 3

The ship got underway at 0815 on 5 April 1998. Initial draft readings were 14'3" (4.34 m) forward and 13'10" (4.22 m) aft. The weather was rainy with reduced winds, and the plan for the day was to complete the 23-knot and 8-knot runs and attempt to get data at 15 knots. The first wave height run (#74) indicated a mid-Sea State 4 seaway (6.7-foot, or 2.04-meter, significant wave height). The first seakeeping run was at 8 knots (RPM=950, 70% prop pitch), head into the waves with motion control on (R=.5, P=.4, Y=.44). The pitch setpoint was 0.8° and relative wind was near beam at about 40 knots. Long swells with wind-blown tops were observed. Occasional shudders were noted at this condition. With motion control off (except for yaw at .48) during the next run (#76), occasional shudders continued and the vessel experienced a particularly severe slam about 9 minutes into the run. Motion control failed and a reboot of that system was required. While maintaining speed, the vessel drifted about 10 degrees off course during this down time. Because the seaway appeared to be increasing, a short wave height measurement was taken (#77) and a near 8-foot (2.44-meter) significant wave height was measured (high Sea State 4). Thirty knots of relative wind at this zero speed run was also recorded.

Runs #78 and #79 were combined to produce a 30-minute, following sea condition data measurement at 23 knots with motion control on (R=.8, P=1.4, Y=.58). Run #80 was a following sea, 23-knot run with motion control off (Y=.4). The canards were set at 2 degrees to prevent the bow from pitching into the waves, but more pronounced pitching and wetness were observed during this run. With motion control remaining off, an 8-knot, starboard quartering wave condition was attempted next (#81). The canards were set back to their nominal position (see Day 1) and a pitch setpoint of 1.2° was input. Relative wind was observed at 21 knots coming from near stern. This condition was repeated (#82) with motion control on (R=.7, P=.7, Y=.4) and the same pitch setpoint.

Having concluded most data runs at 23 and 8 knots, the next run (#83) was a 15-knot port bow quartering sea condition with motion control on (R=.6, P=.44, Y=.4). RPM was set at 2000, propeller pitch at 64%. The pitch setpoint was at 1.3°. This produced a noticeably rough ride with some shudder and pronounced surging. Relative wind was near the beam at 35 knots. During the motion control off run (#84) that followed, the seas appeared to increase and the ship took some heavy slams and wetness. Relative wind was observed more from the bow at about 38 knots.

Continuing with motion control off, the ship came to a starboard beam sea condition at 15 knots (#85). As we approached Barbers Point at the southwest corner of the island,

the wave height seemed to decrease and some wave wrapping was noted, bringing the seas more to the aft quarter. Occasional slams on the struts were noted. Turning to a port beam condition with motion control on (R=.4, P=.66, Y=.42) and a pitch setpoint at 0.5°, Run #86 includes some minor course corrections (approx. 15-20 degrees) during the run to compensate for the wave wrapping. The day ended with two head sea runs: Run #87 with motion control on (settings same as #86) and run #88 with motion control off. Quite a bit of shuddering was noted for the first run while an occasional slam with wetness was observed during the second.

Day 4

On 6 April, initial draft marks were taken prior to transit: Forward port (14'3" or 4.32 m) and starboard (14'2" or 4.32 m); Stern port (14'5" or 4.39 m) and starboard (14'4" or 4.37 m). The first wave height run (#92) indicated a more benign seaway than from the previous test days at a significant wave height of 5 feet (low Sea State 4). The first priority was to conclude the 15-knot series begun the day before with a port stern quartering run (#93) with motion control activated (R=.72, P=.62, Y=.5). The pitch setpoint was reduced early in the run from 0.5° to zero. This was followed by run #94 at the same heading and motion control off. Both runs gave a comfortable ride with some meandering roll and yaw. These runs took the vessel beyond the island lee, so a short 20-minute wave height measurement was made. Waves had increased to a high Sea State 4 with a wind of 25 knots. A repeat starboard bow quartering sea run (#96) at 23 knots was recorded to return the ship to the op area. Motion control was on (R=.62, P=.54, Y=.4) and the pitch setpoint was at 1.3°. We experienced occasional slams and shuddering at this condition and a component of the seaway appeared to be approaching near the beam.

Run #97 was a following sea, 15-knot condition with motion control on (R=.58, P=.66, Y=.5) and a pitch setpoint of 1.0°. This was followed by another short wave measurement (#98) to confirm the seaway at mid-Sea State 4. The next run (#99) was in following waves with motion control off, except for the yaw parameter (=.5). Some port stern quartering waves were observed.

This concluded all Sea State 4 runs, so we took the ship close in on the leeward side of the island in an attempt to find Sea State 3 conditions. A wave height measurement (#100) showed not much change in sea state, but now appeared to be dominated by swell with virtually no wind. A heading directly into the swell (Run #101) was chosen at eight knots (940 RPM with 67% pitch on the prop) with motion control off (yaw at .5). Relative wind was off the starboard bow at 6 knots. Run #102 was the same condition with motion control activated (R=1.32, P=1.0, Y=.5). During this run, the waves became choppier and the wind increased as the ship moved into more open water. Directionality of the waves also seemed to shift to more off the port bow quarter. This completed Day 4, and marked the end of the seakeeping evaluation.

DATA SUMMARY

Sea Conditions

Ten wave height measurements were made during the seakeeping trials period of 3-6 April 1998. Figures 2-5 presents the results of spectral analysis of these runs. On the left side of each figure is the spectral plot with calculated RMS statistic (4× which equals the significant wave height) and encountered modal period (TOE) on top. To the right of each spectral plot is a histogram indicating the distribution of periods and amplitudes of the recorded wave height time histories.

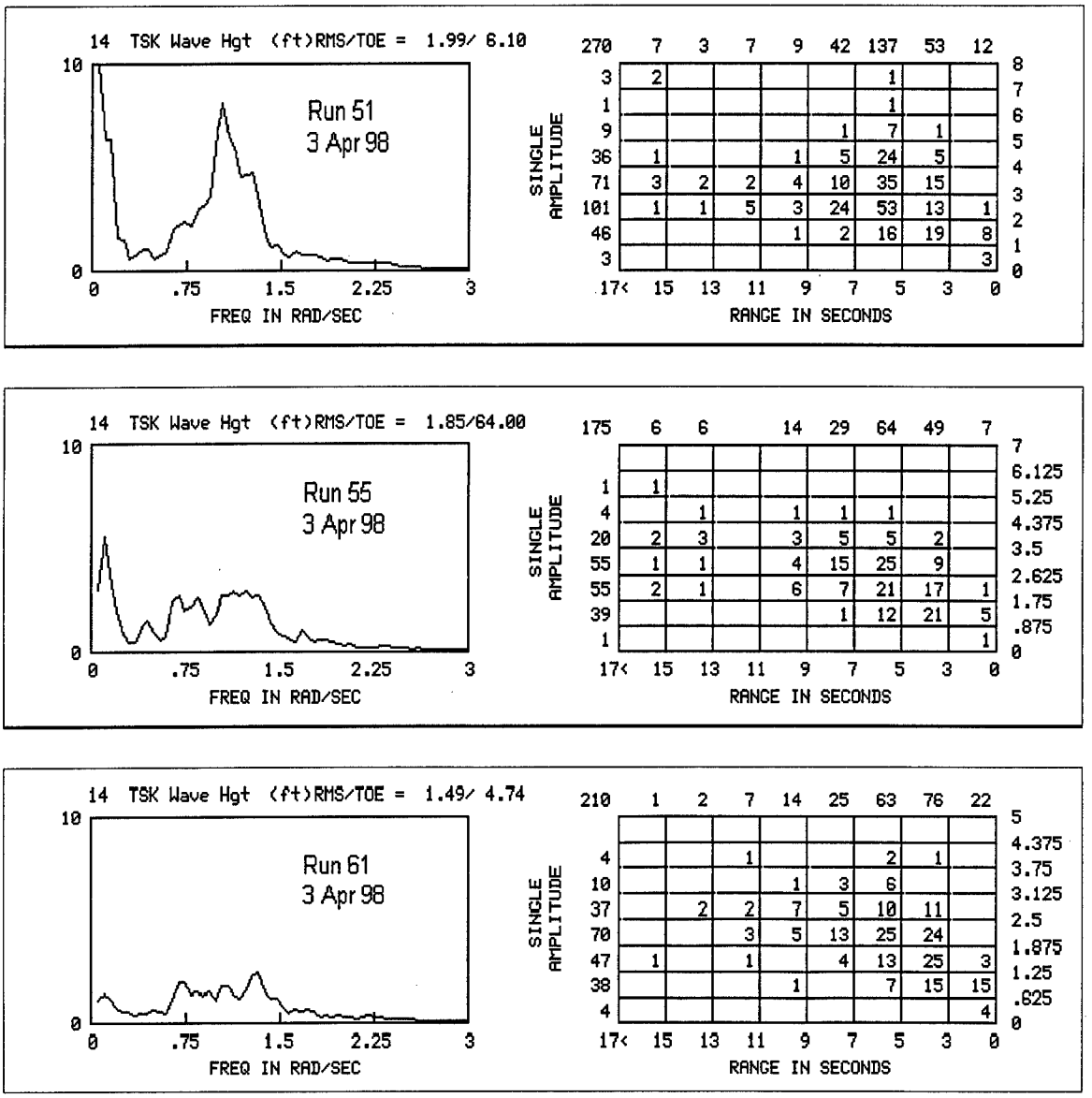


Figure 2 – Wave height spectra from Day 1 of seakeeping trials, 3 April 1998

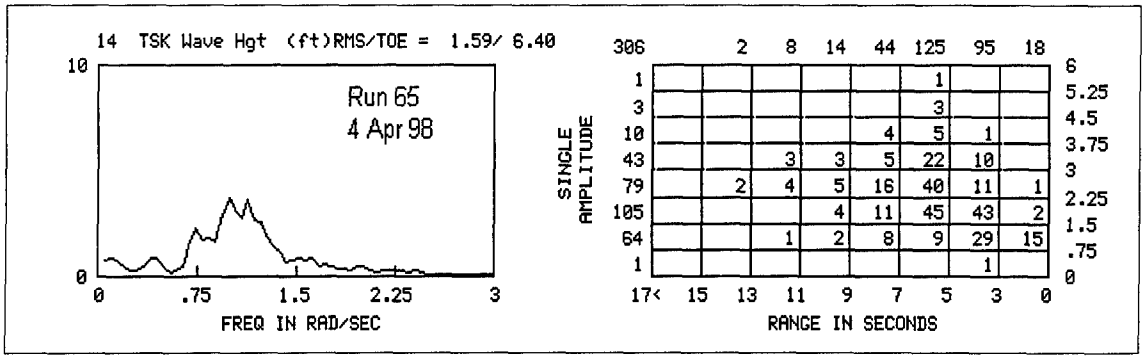
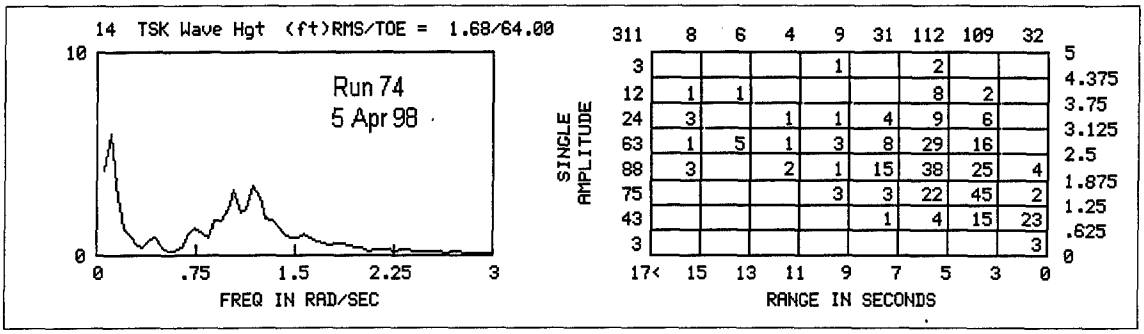


Figure 3 – Wave height spectrum from Day 2 of seakeeping trials, 4 April 1998



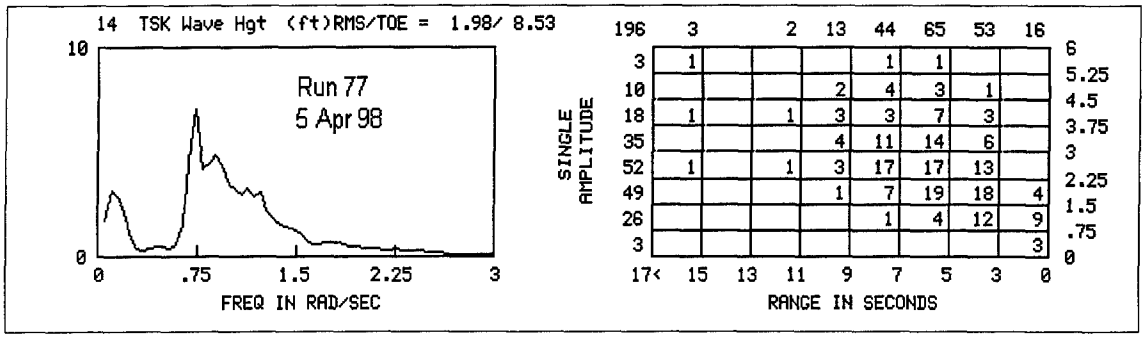


Figure 4 – Wave height spectra from Day 3 of seakeeping trials, 5 April 1998

As can be seen, the encountered sea conditions were dominated by wind-driven waves in the range of 5-9 seconds. From these graphs, there is also an obvious low frequency constituent (64 seconds) as reflected in the TOE values of Runs 55, 74, 95, and 100, although this was not apparent during the trial. However, a swell component in the period range of 9 to 13 seconds was noted, particularly during the last day and as shown in Figure 5.

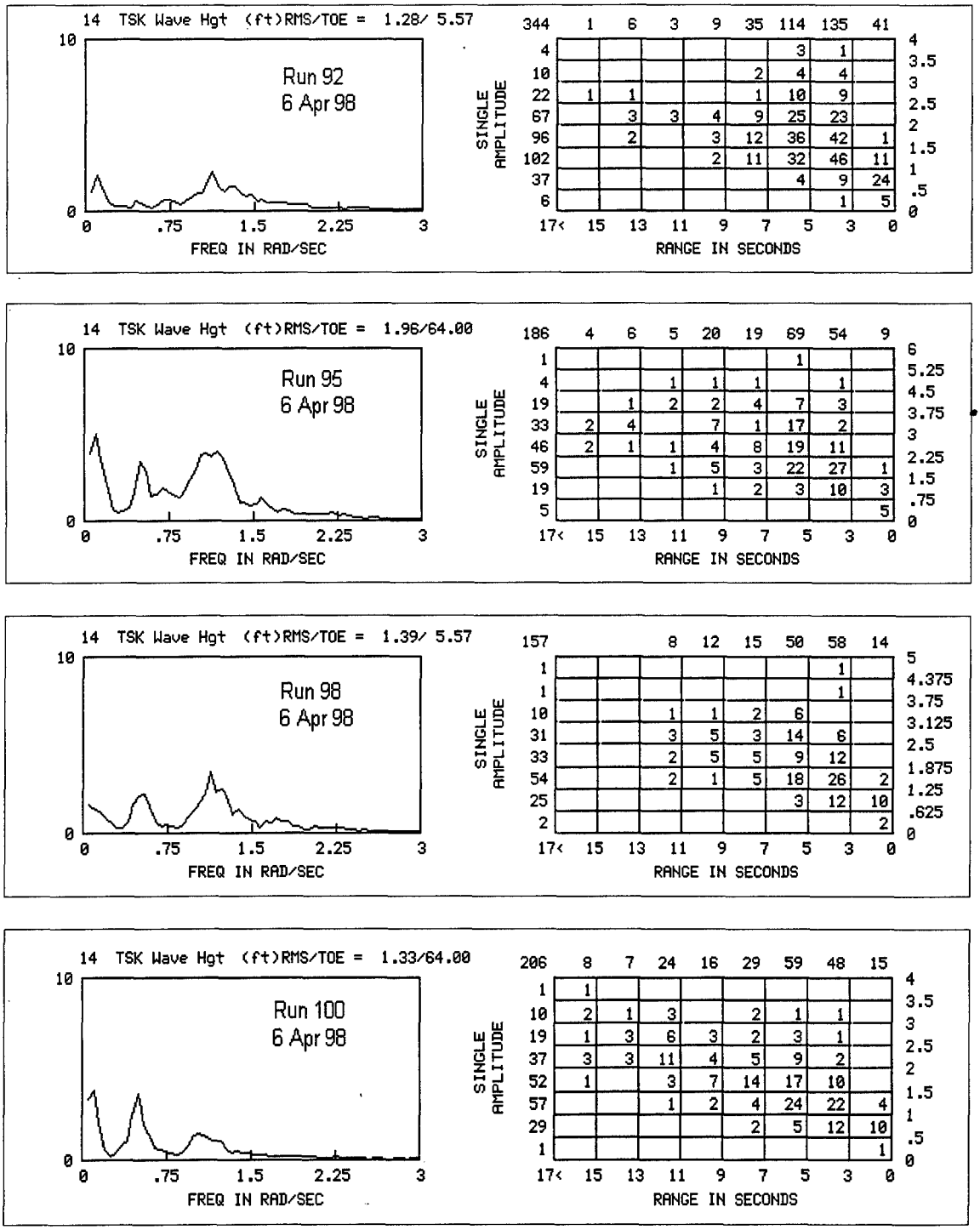


Figure 5 – Wave height spectra from Day 4 of seakeeping trials, 6 April 1998

Ship Motions

A summary of runs and associated ship motions is presented in Table 3. Shown are the ship's nominal speed; status of the motion control system; the mean relative wind speed and direction; the standard deviation values of measured roll and pitch angles, roll and pitch rates; longitudinal, transverse, and vertical accelerations in the mess and female head; the TSK vertical bow acceleration; and the TSK significant wave height (double amplitude). Generally good agreement between the spectral calculation of the significant wave height and that computed from the time histories is noted. The data does show that the seaway encountered the first day, and in particular for the Runs 51 through 60, exceeded Sea State 4 which is defined as a range of significant wave heights between 4.1 and 8.2 feet (1.25 and 2.5 meters).

The largest ship motion excursions that were measured during the sea trials are shown in Table 4. Presented are the maxima and minimums for roll and pitch angles and rates, and for the longitudinal, transverse and vertical accelerations at the two locations. The acceleration data for each run has been adjusted for the recorded means. The most extreme motions occurred the first day of testing during the early runs when Sea State 5 conditions were recorded. The largest roll and pitch angles measured 11.7 degrees (Run 57, starboard beam waves with motion control on) and 7.2 degrees (Run 56, port beam waves with motion control off), respectively. The two accelerometers tracked each other well, the largest differences being noted in the longitudinal acceleration which is heavily dependent on the fore-aft placement of the sensor. The extremes for each instrument occurred at the same conditions: The accelerometer in the mess area recorded a longitudinal maximum of 0.3g during Run 52 (head waves), a transverse maximum of 0.26g during Run 58 (port bow quartering waves), and a very large vertical maximum of 0.6g, also during Run 52. The accelerations measured in the female head were similar: 0.34g longitudinal (Run 52), 0.25g transverse (Run 58), and 0.59g vertical (Run 52).

Finally, Table 5 presents the motion control reduction percentages for comparable headings and speeds. The motion control system aboard SLICE consists of a combination of static and dynamic controls to the four stabilizers. The standard procedure for setting the motion control parameters was a manual input from the bridge. During the trial, time was taken to allow the operator to "optimize" these settings per condition prior to data taking, and to allow him to alter these settings during the run should he feel it warranted. Thus it was hoped that the best ride condition would be obtained and compared with identical conditions with no motion control. Runs where motion control malfunctioned or failed have been noted with an asterisk. A negative value indicates worse motion with motion control active than with it turned off. A review of this data suggests that motion control instituted by this manual method was ineffective. Destabilization occurred often.

Table 3 – Summary of SLICE Ship Motions During Seakeeping Trials, April 1998

Run #	Date	Nom Ship Spd	Motion Control Status	Rel Wind Spd	Rel Wind Dir	Roll Angle	Pitch Angle	Roll Rate	Pitch Rate	Mess Long Acc	Mess Trans Acc	Mess Vert Acc	Head Long Acc	Head Trans Acc	Head Vert Acc	TSK Bow Acc	TSK Wave Ht. (1 ft=.3048 m)
		kts		kts	deg	deg	deg	deg/s	deg/s	g's	g's	g's	g's	g's	g's	g's	ft
				MEAN	MEAN	STDV	STDV	STDV	STDV	STDV	STDV	STDV	STDV	STDV	STDV	STDV	SDA
51	3 Apr	0	-	26.56	178.38	1.61	1.59	1.03	1.87	0.041	0.033	0.047	0.048	0.035	0.047	0.068	8.63
52	3 Apr	23	ON	49.55	329.42	0.78	0.89	0.89	2.11	0.048	0.035	0.085	0.055	0.034	0.085	0.131	9.48
53	3 Apr	23	ON	15.02	93.66	1.98	1.18	0.92	0.47	0.023	0.033	0.014	0.027	0.036	0.014	0.020	13.84
54	3 Apr	23	OFF	13.98	90.19	1.45	1.69	0.70	0.58	0.034	0.023	0.016	0.040	0.025	0.016	0.023	10.70
55	3 Apr	0	-	24.87	335.23	1.50	1.33	1.02	1.54	0.032	0.031	0.037	0.037	0.033	0.038	0.050	7.71
56	3 Apr	23	OFF	26.29	297.74	2.68	1.33	1.85	0.89	0.027	0.046	0.040	0.030	0.050	0.045	0.053	N/A
57	3 Apr	23	ON	33.84	44.58	2.96	1.35	2.26	0.75	0.030	0.047	0.044	0.033	0.052	0.043	0.053	10.30
58	3 Apr	23	ON	39.84	320.29	1.21	0.82	1.52	1.68	0.038	0.045	0.075	0.044	0.046	0.083	0.106	8.68
59	3 Apr	18	ON	38.32	24.30	1.74	0.79	1.60	1.15	0.024	0.035	0.051	0.029	0.036	0.051	0.072	8.55
60	3 Apr	23	ON/OFF	14.24	64.57	1.11	0.91	0.63	0.46	0.021	0.019	0.014	0.025	0.020	0.014	0.020	8.52
61	3 Apr	0	-	21.24	325.05	1.23	1.16	0.85	1.32	0.027	0.025	0.035	0.032	0.027	0.035	0.047	6.17
62	3 Apr	23	OFF	44.87	338.02	0.49	0.60	0.59	1.34	0.033	0.028	0.062	0.038	0.028	0.061	0.089	7.86
63	3 Apr	23	ON	44.15	339.61	0.47	0.76	0.62	1.65	0.036	0.028	0.069	0.041	0.028	0.069	0.101	7.10
65	4 Apr	0	-	25.45	335.29	1.24	1.57	0.77	1.78	0.041	0.025	0.047	0.046	0.026	0.043	0.061	6.57
66	4 Apr	8	ON	16.33	137.29	1.94	1.60	1.22	1.03	0.025	0.035	0.019	0.027	0.038	0.015	0.023	7.78
67	4 Apr	8	OFF	14.35	123.30	1.37	1.31	0.84	0.90	0.018	0.024	0.014	0.019	0.026	0.012	0.016	7.74
68	4 Apr	8	OFF	26.92	305.82	0.94	0.93	0.68	1.17	0.032	0.028	0.042	0.033	0.029	0.043	0.050	6.13
70	4 Apr	8	ON	30.76	307.53	1.21	1.24	0.83	1.53	0.035	0.035	0.047	0.036	0.037	0.049	0.060	7.14
71	4 Apr	8	ON	28.07	62.96	2.31	0.84	1.93	0.73	0.017	0.040	0.029	0.020	0.044	0.031	0.033	7.71
72	4 Apr	8	OFF	24.69	62.63	2.47	0.81	1.97	0.68	0.016	0.042	0.025	0.018	0.046	0.027	0.027	7.70
73	4 Apr	23	OFF	40.00	276.14	0.64	0.34	0.77	0.77	0.022	0.030	0.042	0.025	0.030	0.039	0.055	5.00
74	5 Apr	0	-	24.23	324.49	1.08	1.34	0.64	1.37	0.035	0.023	0.039	0.038	0.024	0.036	0.050	7.03
75	5 Apr	8	ON	31.82	326.50	0.85	1.04	0.60	1.32	0.031	0.022	0.044	0.034	0.023	0.044	0.057	9.48
76	5 Apr	8	OFF	33.02	346.14	0.93	1.20	0.65	1.51	0.037	0.025	0.052	0.041	0.025	0.051	0.072	N/A
77	5 Apr	0	-	24.90	332.37	1.52	1.85	0.98	1.95	0.044	0.032	0.052	0.048	0.034	0.048	0.070	8.09
78	5 Apr	23	ON	4.99	120.64	1.59	0.88	0.84	0.49	0.023	0.029	0.017	0.025	0.032	0.017	0.022	9.49
79	5 Apr	23	ON	3.40	126.77	1.66	0.99	0.78	0.52	0.024	0.030	0.018	0.026	0.033	0.017	0.024	10.96
80	5 Apr	23	OFF	2.49	200.22	1.60	1.53	0.87	0.52	0.029	0.030	0.017	0.031	0.033	0.016	0.023	10.19
81	5 Apr	8	OFF	16.78	119.91	1.68	1.29	1.10	0.94	0.023	0.030	0.018	0.025	0.033	0.016	0.025	8.57
82	5 Apr	8	ON	14.25	116.92	1.57	1.27	0.99	0.89	0.022	0.028	0.018	0.024	0.031	0.017	0.025	7.88
83	5 Apr	15	ON	32.61	331.48	0.91	0.76	0.75	1.18	0.031	0.027	0.043	0.033	0.028	0.043	0.060	7.76
84	5 Apr	15	OFF	33.47	323.39	0.84	0.84	0.94	1.42	0.039	0.037	0.058	0.042	0.037	0.061	0.080	9.69
85	5 Apr	15	OFF	22.16	57.01	1.92	1.17	1.55	0.69	0.019	0.033	0.025	0.020	0.036	0.024	0.029	8.81
86	5 Apr	15	ON	22.34	300.71	1.81	0.98	1.61	0.96	0.023	0.040	0.036	0.024	0.043	0.042	0.046	7.70
87	5 Apr	15	ON	35.82	300.66	1.02	0.80	1.05	1.47	0.038	0.032	0.056	0.042	0.033	0.055	0.075	6.70
88	5 Apr	15	OFF	36.54	285.84	0.93	0.66	0.98	1.23	0.034	0.030	0.052	0.038	0.031	0.051	0.070	6.55
92	6 Apr	0	-	21.98	335.89	0.93	0.97	0.59	0.98	0.026	0.018	0.026	0.028	0.019	0.024	0.034	5.31
93	6 Apr	15	ON	8.07	251.40	1.55	0.91	0.90	0.42	0.014	0.030	0.012	0.015	0.033	0.013	0.015	9.35
94	6 Apr	15	OFF	6.57	247.62	1.67	1.31	1.10	0.52	0.022	0.032	0.015	0.023	0.035	0.017	0.019	10.03
95	6 Apr	0	-	20.96	120.58	1.40	1.34	0.89	1.55	0.036	0.028	0.042	0.040	0.030	0.041	0.057	7.94
96	6 Apr	23	ON	36.47	26.51	1.68	0.69	1.63	0.86	0.022	0.038	0.046	0.025	0.040	0.044	0.060	7.71
97	6 Apr	15	ON	5.95	100.81	1.25	0.84	0.52	0.37	0.015	0.023	0.015	0.016	0.026	0.016	0.018	9.21
98	6 Apr	0	-	17.95	341.11	1.22	1.07	0.81	1.22	0.029	0.024	0.027	0.032	0.026	0.027	0.037	6.14
99	6 Apr	15	OFF	2.83	101.11	1.18	1.05	0.63	0.42	0.019	0.024	0.021	0.021	0.027	0.021	0.024	7.54
100	6 Apr	0	-	2.54	164.03	0.85	1.03	0.66	1.05	0.025	0.018	0.028	0.026	0.020	0.027	0.036	5.56
101	6 Apr	8	OFF	5.92	101.37	0.70	0.63	0.44	0.70	0.018	0.014	0.021	0.019	0.015	0.020	0.029	5.73
102	6 Apr	8	ON	25.30	330.07	0.64	0.80	0.43	0.83	0.021	0.015	0.022	0.022	0.015	0.021	0.031	5.74

Table 4 – Maximum Ship Motion Excursions During SLICE Seakeeping Trials, April 1998

Run #	Roll Angle		Roll Rate		Pitch Angle		Pitch Rate		Mess Long Acc		Mess Tran Acc		Mess Vert Acc		Head Long Acc		Head Tran Acc		Head Vert Acc	
	deg		deg/sec		deg		deg/sec		g's		g's		g's		g's		g's		g's	
	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX
51	-5.04	5.51	-3.41	3.44	-6.60	5.84	-7.76	7.14	-0.176	0.139	-0.125	0.136	-0.146	0.189	-0.204	0.168	-0.133	0.144	-0.147	0.169
52	-2.71	3.31	-3.92	4.88	-4.26	2.77	-11.67	8.34	-0.297	0.161	-0.151	0.163	-0.294	0.601	-0.337	0.219	-0.125	0.156	-0.280	0.585
53	-6.33	10.14	-3.46	4.71	-5.15	3.76	-1.58	1.79	-0.117	0.093	-0.131	0.175	-0.068	0.095	-0.135	0.106	-0.145	0.191	-0.065	0.086
54	-4.69	5.77	-2.87	3.00	-5.29	5.90	-1.97	2.41	-0.177	0.090	-0.094	0.100	-0.077	0.102	-0.200	0.108	-0.099	0.106	-0.069	0.099
55	-3.66	6.26	-3.65	3.92	-5.30	3.83	-4.83	5.12	-0.099	0.101	-0.123	0.119	-0.125	0.125	-0.116	0.111	-0.137	0.121	-0.130	0.132
56	-8.14	10.42	-7.36	5.83	-5.67	7.23	-3.44	4.73	-0.130	0.111	-0.139	0.169	-0.138	0.213	-0.146	0.121	-0.143	0.193	-0.175	0.241
57	-11.69	8.44	-7.66	8.20	-5.48	2.83	-2.83	2.63	-0.129	0.093	-0.180	0.228	-0.160	0.205	-0.134	0.102	-0.203	0.248	-0.170	0.188
58	-1.90	7.61	-5.87	6.02	-4.55	1.56	-7.05	5.82	-0.227	0.141	-0.260	0.188	-0.255	0.408	-0.246	0.156	-0.250	0.184	-0.294	0.449
59	-6.14	5.58	-6.46	5.41	-4.60	2.12	-4.07	4.82	-0.113	0.100	-0.108	0.190	-0.170	0.221	-0.116	0.140	-0.119	0.197	-0.152	0.225
60	-2.47	4.98	-2.21	2.53	-3.66	3.21	-1.68	2.89	-0.113	0.070	-0.060	0.086	-0.072	0.085	-0.126	0.078	-0.065	0.094	-0.067	0.079
61	-2.62	4.98	-3.19	2.43	-4.31	3.40	-4.93	4.68	-0.094	0.095	-0.072	0.106	-0.103	0.110	-0.109	0.106	-0.081	0.106	-0.107	0.114
62	-0.42	3.52	-4.02	1.78	-3.50	0.88	-4.73	4.38	-0.147	0.112	-0.120	0.141	-0.177	0.311	-0.165	0.121	-0.125	0.140	-0.193	0.287
63	0.30	3.88	-2.84	1.90	-4.13	2.10	-7.83	5.43	-0.275	0.114	-0.111	0.118	-0.231	0.442	-0.303	0.134	-0.109	0.111	-0.235	0.441
65	-3.75	5.37	-2.45	3.02	-4.89	5.27	-7.03	7.00	-0.188	0.123	-0.081	0.094	-0.146	0.260	-0.209	0.172	-0.088	0.098	-0.128	0.235
66	-4.72	6.78	-3.80	3.90	-5.52	4.34	-3.39	3.99	-0.104	0.082	-0.098	0.112	-0.070	0.091	-0.113	0.088	-0.104	0.122	-0.047	0.076
67	-3.98	5.50	-3.14	3.05	-3.12	4.93	-2.92	2.75	-0.061	0.066	-0.079	0.092	-0.056	0.042	-0.064	0.072	-0.086	0.100	-0.045	0.040
68	-0.70	7.28	-3.50	5.49	-3.25	3.15	-5.32	4.82	-0.136	0.108	-0.195	0.172	-0.167	0.258	-0.137	0.118	-0.170	0.167	-0.175	0.286
70	-1.79	7.39	-3.04	5.05	-4.45	3.52	-5.85	5.04	-0.141	0.123	-0.180	0.177	-0.161	0.176	-0.143	0.124	-0.179	0.174	-0.161	0.193
71	-8.98	7.14	-6.92	7.61	-3.05	2.36	-2.43	2.55	-0.057	0.064	-0.127	0.176	-0.104	0.128	-0.066	0.077	-0.133	0.185	-0.112	0.121
72	-9.40	7.21	-6.53	5.88	-3.22	2.67	-2.63	2.53	-0.059	0.059	-0.118	0.168	-0.092	0.100	-0.067	0.064	-0.122	0.175	-0.099	0.113
73	-1.43	2.70	-3.68	2.65	-3.97	-0.96	-3.31	2.82	-0.095	0.069	-0.104	0.113	-0.146	0.170	-0.107	0.086	-0.101	0.122	-0.144	0.154
74	-2.14	5.89	-2.36	2.24	-4.76	3.99	-4.75	4.16	-0.131	0.111	-0.086	0.080	-0.125	0.140	-0.147	0.122	-0.084	0.080	-0.115	0.125
75	-2.36	3.72	-2.38	2.17	-4.04	3.49	-5.59	4.94	-0.132	0.100	-0.097	0.097	-0.166	0.242	-0.146	0.115	-0.098	0.096	-0.171	0.226
76	-3.07	3.88	-3.21	2.39	-5.14	5.51	-8.39	6.78	-0.257	0.151	-0.125	0.133	-0.214	0.357	-0.284	0.160	-0.116	0.122	-0.208	0.315
77	-3.94	5.60	-3.80	3.07	-5.18	6.68	-7.03	6.14	-0.146	0.133	-0.106	0.116	-0.135	0.166	-0.158	0.157	-0.118	0.122	-0.134	0.153
78	-3.52	6.00	-3.28	2.65	-3.88	2.22	-1.51	2.36	-0.090	0.070	-0.100	0.094	-0.101	0.071	-0.096	0.076	-0.103	0.106	-0.092	0.066
79	-2.93	7.02	-2.50	2.12	-3.50	2.07	-1.46	2.33	-0.090	0.075	-0.081	0.118	-0.067	0.068	-0.098	0.081	-0.088	0.134	-0.064	0.058
80	-5.47	6.18	-3.28	3.66	-3.98	5.66	-1.75	2.28	-0.178	0.090	-0.124	0.100	-0.064	0.147	-0.195	0.094	-0.137	0.109	-0.070	0.130
81	-5.13	6.60	-3.43	4.29	-4.13	5.32	-4.24	3.19	-0.081	0.099	-0.092	0.104	-0.078	0.070	-0.093	0.098	-0.104	0.121	-0.064	0.063
82	-3.97	5.86	-3.65	3.14	-4.06	4.30	-2.80	3.14	-0.079	0.068	-0.102	0.097	-0.058	0.064	-0.086	0.074	-0.110	0.105	-0.061	0.061
83	-1.66	4.56	-2.82	2.68	-3.78	2.17	-5.37	4.48	-0.156	0.129	-0.103	0.102	-0.150	0.209	-0.167	0.134	-0.105	0.098	-0.158	0.178
84	-0.82	5.51	-4.43	5.51	-2.91	3.04	-5.85	4.70	-0.192	0.128	-0.196	0.214	-0.181	0.306	-0.207	0.137	-0.187	0.200	-0.187	0.320
85	-6.31	7.06	-6.14	5.88	-2.80	5.45	-2.46	2.84	-0.089	0.058	-0.130	0.185	-0.118	0.177	-0.101	0.063	-0.147	0.177	-0.122	0.140
86	-4.89	8.40	-5.19	6.34	-3.88	3.08	-3.14	3.41	-0.088	0.079	-0.132	0.148	-0.132	0.130	-0.093	0.088	-0.135	0.158	-0.154	0.158
87	-2.80	4.49	-4.29	3.39	-3.28	1.88	-5.19	4.99	-0.171	0.134	-0.112	0.144	-0.181	0.290	-0.191	0.157	-0.110	0.145	-0.173	0.258
88	-2.97	4.21	-3.89	3.39	-2.21	2.52	-4.53	4.80	-0.159	0.111	-0.117	0.146	-0.153	0.296	-0.179	0.119	-0.111	0.139	-0.165	0.284
92	-3.37	4.26	-2.58	2.43	-3.35	2.72	-3.48	3.77	-0.088	0.080	-0.064	0.072	-0.090	0.095	-0.097	0.098	-0.070	0.081	-0.084	0.089
93	-3.46	7.14	-2.99	3.46	-3.15	2.72	-1.36	1.70	-0.052	0.062	-0.097	0.115	-0.044	0.047	-0.057	0.066	-0.109	0.129	-0.045	0.049
94	-4.45	6.36	-3.89	4.05	-2.78	5.60	-1.73	2.06	-0.107	0.072	-0.107	0.103	-0.053	0.057	-0.117	0.078	-0.120	0.116	-0.053	0.064
95	-3.79	5.07	-2.89	3.24	-5.54	4.71	-6.51	6.31	-0.132	0.120	-0.103	0.096	-0.140	0.159	-0.149	0.154	-0.114	0.106	-0.134	0.147
96	-5.60	6.18	-6.34	5.46	-3.91	0.81	-5.17	4.97	-0.144	0.092	-0.117	0.213	-0.173	0.308	-0.167	0.115	-0.118	0.206	-0.167	0.268
97	-2.23	5.61	-2.53	1.51	-3.91	1.95	-1.31	1.40	-0.058	0.051	-0.073	0.071	-0.054	0.048	-0.064	0.054	-0.079	0.078	-0.050	0.050
98	-2.72	4.72	-2.94	2.41	-4.52	2.83	-4.32	3.85	-0.095	0.093	-0.078	0.080	-0.088	0.096	-0.106	0.107	-0.084	0.084	-0.080	0.093
99	-2.06	5.92	-2.60	2.09	-2.66	4.52	-1.48	1.40	-0.070	0.072	-0.088	0.096	-0.073	0.076	-0.071	0.079	-0.098	0.106	-0.074	0.078
100	-1.04	4.63	-2.28	2.04	-3.72	2.66	-3.22	3.04	-0.080	0.073	-0.074	0.053	-0.083	0.107	-0.088	0.077	-0.078	0.059	-0.081	0.100
101	-1.07	4.65	-2.45	1.58	-2.65	2.50	-2.87	2.67	-0.072	0.058	-0.065	0.058	-0.066	0.077	-0.078	0.064	-0.070	0.062	-0.070	0.076
102	-0.32	4.53	-1.87	1.38	-2.93	2.63	-2.61	3.48	-0.081	0.076	-0.059	0.066	-0.087	0.077	-0.089	0.082	-0.064	0.063	-0.078	0.076

Table 5 – Comparison of Ship Responses with Motion Control On and Off

Run #	Wave Heading	Date/Time	Motion Control	Nom. Ship Speed	Roll Angle		Roll Rate		Pitch Angle		Pitch Rate		Mess Long Acc		Mess Tran Acc		Mess Vert Acc		Head Long Acc		Head Tran Acc		Head Vert Acc	
					STDV	Reduction	STDV	Reduction	STDV	Reduction	STDV	Reduction	STDV	Reduction	STDV	Reduction	STDV	Reduction	STDV	Reduction	STDV	Reduction	STDV	Reduction
				kt	deg	%	deg/s	%	deg	%	deg/s	%	g's	%	g's	%	g's	%	g's	%	g's	%	g's	%
53*	Stbd Qtr	031051Z APR98	ON	23	1.98		0.92		1.18		0.47		0.023		0.033		0.014		0.027		0.036		0.014	
54	Stbd Qtr	031143Z APR98	OFF	23	1.45	-36.52	0.70	-32.76	1.69	29.85	0.58	19.72	0.034	32.45	0.023	-42.55	0.016	11.71	0.040	33.48	0.025	-41.99	0.016	9.51
57	Beam	031321Z APR98	ON	23	2.96		2.26		1.35		0.75		0.030		0.047		0.044		0.033		0.052		0.043	
56*	Beam	031245Z APR98	OFF	23	2.68	-10.35	1.85	-22.07	1.33	-2.02	0.89	15.80	0.027	-10.88	0.046	-1.99	0.040	-11.17	0.030	-8.39	0.050	-3.61	0.045	4.09
78	Follow	051120Z APR98	ON	23	1.59		0.84		0.88		0.49		0.023		0.029		0.017		0.025		0.032		0.017	
79	Follow	051152Z APR98	ON	23	1.66		0.78		0.99		0.52		0.024		0.030		0.018		0.026		0.033		0.017	
80	Follow	051203Z APR98	OFF	23	1.60	0.92	0.87	2.77	1.53	42.49	0.52	6.07	0.029	21.41	0.030	2.05	0.017	-0.11	0.031	18.84	0.033	2.77	0.016	-3.59
63	Head	031712Z APR98	ON	23	0.47		0.62		0.76		1.65		0.036		0.028		0.069		0.041		0.028		0.069	
62	Head	031648Z APR98	OFF	23	0.49	2.97	0.59	-4.83	0.60	-26.43	1.34	-22.91	0.033	-10.20	0.028	0.97	0.062	-11.35	0.038	-9.71	0.028	1.93	0.061	-13.78
66	Follow	4-Apr-98	ON	8	1.94		1.22		1.60		1.03		0.025		0.035		0.019		0.027		0.038		0.015	
67	Follow	4-Apr-98	OFF	8	1.37	-40.90	0.84	-46.15	1.31	-22.38	0.90	-15.32	0.018	-40.79	0.024	-46.55	0.014	-33.86	0.019	-40.63	0.026	-48.11	0.012	-25.88
70	Port Bow	4-Apr-98	ON	8	1.21		0.83		1.24		1.53		0.035		0.035		0.047		0.036		0.037		0.049	
68	Port Bow	4-Apr-98	OFF	8	0.94	-28.00	0.68	-22.06	0.93	-33.69	1.17	-30.15	0.032	-11.61	0.028	-25.31	0.042	-12.03	0.033	-11.17	0.029	-28.91	0.043	-15.56
71	Beam	4-Apr-98	ON	8	2.31		1.93		0.84		0.73		0.017		0.040		0.029		0.020		0.044		0.031	
72	Beam	4-Apr-98	OFF	8	2.47	6.47	1.97	1.80	0.81	-3.13	0.68	-7.94	0.016	-10.30	0.042	5.28	0.025	-17.07	0.018	-9.09	0.046	6.33	0.027	-15.65
82	Stbd Qtr	051313Z APR98	ON	8	1.57		0.99		1.27		0.89		0.022		0.028		0.018		0.024		0.031		0.017	
81	Stbd Qtr	051242Z APR98	OFF	8	1.68	6.57	1.10	9.56	1.29	1.25	0.94	5.52	0.023	0.94	0.030	4.75	0.018	-3.26	0.025	1.47	0.033	4.54	0.016	-6.26
102	Head	061551Z APR98	ON	8	0.64		0.43		0.80		0.83		0.021		0.015		0.022		0.022		0.015		0.021	
101	Head	061519Z APR98	OFF	8	0.70	8.13	0.44	4.17	0.63	-27.21	0.70	-18.94	0.018	-14.85	0.014	-3.81	0.021	-3.60	0.019	-14.79	0.015	-2.39	0.020	-1.60
83	Port Bow	051356Z APR98	ON	15	0.91		0.75		0.76		1.18		0.031		0.027		0.043		0.033		0.028		0.043	
84	Port Bow	051430Z APR98	OFF	15	0.84	-7.62	0.94	20.80	0.84	10.44	1.42	17.14	0.039	20.56	0.037	27.59	0.058	25.88	0.042	20.64	0.037	25.80	0.061	29.53
86	Beam	051538Z APR98	ON	15	1.81		1.61		0.98		0.96		0.023		0.040		0.036		0.024		0.043		0.042	
85	Beam	051502Z APR98	OFF	15	1.92	5.38	1.55	-4.20	1.17	16.43	0.69	-39.65	0.019	-20.24	0.033	-24.08	0.025	-46.36	0.020	-20.46	0.036	-17.97	0.024	-73.95
87	Head	051620Z APR98	ON	15	1.02		1.05		0.80		1.47		0.038		0.032		0.056		0.042		0.033		0.055	
88	Head	051655Z APR98	OFF	15	0.93	-9.41	0.98	-7.56	0.66	-20.25	1.23	-19.61	0.034	-10.47	0.030	-3.71	0.052	-6.79	0.038	-9.95	0.031	-4.57	0.051	-7.43
93	Port Qtr	061054Z APR98	ON	15	1.55		0.90		0.91		0.42		0.014		0.030		0.012		0.015		0.033		0.013	
94	Port Qtr	061131Z APR98	OFF	15	1.67	7.43	1.10	18.20	1.31	30.83	0.52	19.67	0.022	33.75	0.032	8.01	0.015	17.69	0.023	32.68	0.035	8.00	0.017	20.74
97	Follow	061301Z APR98	ON	15	1.25		0.52		0.84		0.37		0.015		0.023		0.015		0.016		0.026		0.016	
99	Follow	061354Z APR98	OFF	15	1.18	-6.25	0.63	17.37	1.05	20.43	0.42	12.98	0.019	23.01	0.024	4.39	0.021	27.22	0.021	22.23	0.027	3.88	0.021	24.45

SUMMARY

A fairly comprehensive set of headings and speeds were examined for SLICE in Sea State 4. This sea state represents the most probable sea conditions that can be expected in the open oceans of the Northern Hemisphere (see Table 6). The seakeeping characteristics of SLICE can be described as SWATH-like. Sea conditions approaching low Sea State 5 produced a relatively stable ride for a vessel this size. Extreme motions were modest with the highest roll and pitch values recorded at 11.7 and 8.2 degrees, respectively. The maximum longitudinal, transverse, and vertical accelerations measured were 0.34, 0.26, and 0.6g's, respectively. In the higher sea state conditions, some slamming and hull shuddering were noted.

The motion control system, as used throughout the trial period, proved to be generally ineffective. Data showed that destabilization occurred as often as the stabilizing effect of the system. While impossible to characterize the specific causes of this problem, a suspected contributor to the "hit or miss" symptoms was the manual input by the operator. This process allowed for variability and inconsistency from run to run.

Table 6 - Sea State Definition and Annual Probability of Occurrence in the Open Ocean Northern Hemisphere

SEA STATE	PERCENTAGE PROBABILITY	SIGNIFICANT WAVE HEIGHTS		MODAL WAVE PERIODS	SUSTAINED WIND SPEED
		(ft)	(m)	(sec)	(kt)
0-1	0	0.0 - 0.3	0.0 – 0.1	--	0 - 6
2	5.7	0.3 - 1.6	0.1 – 0.5	3.0 - 15.0	7 -10
3	19.7	1.6 - 4.1	0.5 – 1.25	5.2 - 15.5	11 - 16
4	28.3	4.1 - 8.2	1.25 – 2.5	5.9 - 15.5	17 -21
5	19.5	8.2 - 13.1	2.5- 4.0	7.2 - 16.5	22 - 27
6	17.5	13.1 - 19.7	4.0 – 6.0	9.3 - 16.5	28 - 47
7	7.6	19.7 - 29.5	6.0 – 9.0	10.0 - 17.2	48 - 55
8	1.7	29.5 - 45.5	9.0 – 14.0	13.0 - 18.4	56 - 63
>8	0.1	>45.5	>14.0	20.0	>63

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